

PHYSICAL ALTERNATIVE TO THE DARK ENERGY PARADIGM

A. Sapar

Tartu Observatory, 61602 Tõravere, Estonia; sapar@to.ee

Received: 2013 October 9; revised October 22; accepted: November 6

Abstract. The physical nature of the presently dominating enigmatic dark energy in the expanding universe is demonstrated to be explainable as an excess of the kinetic energy with respect to its potential energy. According to traditional Friedman cosmology, any non-zero value of the total energy integral is ascribed to the space curvature. However, as we show, in the flat universe the total energy also can be different from zero. Initially, a very small excess of kinetic energy originates from the early universe. The present observational data show that our universe has probably a flat space with an excess of kinetic energy. The evolutionary scenario shows that the universe presently is in the transitional stage where its radial coordinate expansion approaches the velocity of light. A possibility of the closed Bubble universe with the local Big Bang and everlasting expansion is demonstrated. Dark matter can be essentially contributed by the non-relativistic massive neutrinos, which have cooled to very low temperatures and velocities thus favoring the formation of the observed broad equipotential wells in galaxies.

Key words: cosmology: theory, dark energy, dark matter, neutrinos

1. INTRODUCTION

During the last decades a strange situation in fundamental cosmology has arisen. On the observational side, a considerable progress has been made, with the results appreciated by awarding in 2011 the Nobel Prize to S. Perlmutter, A. Riess and B. P. Schmidt. In their Nobel Lectures, these eminent scientists addressed theorists with an appeal to unveil the physical nature of the mysterious dark energy. A large number of papers have been devoted to the problem, but, unfortunately, without a considerable success.

This circumstance impelled us to propose a physically clear and simple alternative concept of the nature of dark energy. Such a possibility was discussed by us about a half-century ago (Sapar 1964). In order to explain the problem in more details, it is necessary to turn directly to the Einstein equations of general relativity. As it was emphasized by Albert Einstein himself, the concept of the curved space-time expressed in the curvature tensor is elegant and has a deep physical nature. Einstein perceived that the energy-momentum tensor, equalized to his elegant tensor of space-time geometry, is not perfect. The problems, connected with the meaning and necessity of the cosmological constant in the energy-momentum tensor, are also known. From a new standpoint we try to interpret the recent observational data connected with (1) the Ia supernovae (hereafter SNe) as standard

candles for cosmology, and (2) the results of the Antarctic high-balloon Boomerang mission which has investigated the fine structure of the cosmic microwave background (CMB) angular power spectrum and has added important contribution to the constraints on the variety of different theoretically assumed forms of the energy-momentum tensor. The results of the Boomerang mission have added an important constraint, that the space in cosmological dimensions with high fidelity turns out to be flat.

The study of SNe has shown that the expansion of the universe exceeds somewhat the expected expansion rate, corresponding to the accepted cosmological standard model with the observed matter, dark matter and dark energy. The result has been predominantly treated as mysterious, which demands modification of the Friedman equations. Different additional hypothetical source-terms were added to these equations, and presently there is a wide variety of proposed model-equations for the universe. The best known of them add the quintessence term or the repulsion term of the cosmological constant, which gives an exponential expansion of the universe in the future.

During the last decade, the intensive observational studies of the law and nature of the expansion of the universe have been accomplished with the large ground-based and orbital telescopes, treating the light curves of SNe as standard candles. The main result of these investigations – the accelerating expansion of the flat-space universe containing about 70% of enigmatic dark energy – has been generally acknowledged as a paradigm by the main-stream cosmologists. An early paper with the results of the SNe project was published by Goldhaber & Perlmutter (1998). Important results were also obtained by the international mission Supernova Legacy Survey (SLS), based on the dependence 'redshift versus observed stellar magnitude' of SNe. A detailed analysis of the methods applied in the study and a review of the SLS mission results were published by Astier et al. (2006). The paper has 42 authors from 18 institutions of 7 countries. Leibundgut (2009) emphasized that with the SLS project a new era in observational cosmology has been started. In above mentioned papers and the Nobel lectures the project leaders appeal to theorists for their help in the unraveling the physical nature of dark energy. Summarizing the results of the Boomerang mission, considering the angular structure of CMB, MacTavish et al. (2006) show, that our universe is very close to being flat.

2. PHYSICAL AND HISTORICAL BACKGROUND

The situation described above seems to be too complicated, and we prefer to start from the conservative Occam's razor principle, which suggests to avoid introducing any new parameters of unknown nature without the extreme need. The present situation in fundamental cosmology is strange in the aspect that the total energy integral in the flat-space universe has been assumed to be strictly zero. This seems to be a physically groundless constraint. From such a treatment of the usual Friedman equations follows, that even a minimal non-zero value of the total energy in the universe is inevitably related to the space curvature. Such a point of view seems to be unacceptable.

In order to make a step forward in our introductory discussion, we mention that the main additional assumptions to be added to the Friedman equations are the matter state equations. This is a crucial point in the interpretation and study of the Friedman equations. As we have shown many years ago (Sapar 1964) in

Publications of Tartu Observatory (written in Russian, but with a quite detailed English summary), an important class of special Friedman equations of state can be given by

$$G\rho_n R^n = C_n, \quad (n-3)\rho_n = 3P_n c^{-2}. \quad (1)$$

Here G is the gravitational constant, ρ_n and P_n are the partial densities of matter and pressure, and C_n are the constants. Every such component can be considered as a contribution to the equation of total energy and total pressure in the equations of the evolution of the universe. As we see, the case $n = 3$ corresponds to the usual non-relativistic matter, being at rest in the co-moving cosmological coordinate framework, and the case $n = 4$ corresponds to the radiation, which is redshifted due to expansion of the universe. Most of the present cosmologists write the equation in the form

$$p_n \propto w_n \rho_n, \quad (2)$$

where the index w_n , which we name the pressure index, is given by

$$w_n = \frac{n-3}{3}. \quad (3)$$

Thus, $w_n = 0$ for the classical matter and $w_n = 1/3$ for the radiation. In the evolving universe the index changes from $1/3$ to 0 . The equations, which specify such an evolutionary change, have been published recently (Sapar 2011).

If in the evolving universe there are several contributors to the matter density which interact only gravitationally, then for the total density we can write:

$$G\rho = \sum_n \frac{C_n}{R^n}. \quad (4)$$

For the pressure we obtain in a similar way the equation

$$GP = c^2 \sum_n w_n \frac{C_n}{R^n}. \quad (5)$$

Now let us check which values of the parameter n are urgently needed in the present context. First, it is inevitable to remove the constraint that in the flat space only the zero value of total energy is possible. Thus, we start from the Einstein equation in the form, given in our earlier paper (Sapar 1964, Eq. 3.114), but repeated here in somewhat differently scaled form:

$$\frac{\dot{R}^2}{c^2} = \frac{\alpha}{R} + \frac{\beta}{R^2} + \kappa - k. \quad (6)$$

The non-zero positive constant κ is the constant of energy, corresponding to the energy-momentum tensor, which can also be non-zero in the flat space, where the curvature constant $k = 0$. The constant κ can be also added to the cases $k = \pm 1$. This means that, in addition to the rest-matter and radiation, we need also the term corresponding to $n = 2$. This term is a very natural integral of energy in the flat space too. This energy might be very small and unnoticeable parameter during the early evolutionary stages of the universe, like the asymmetry of the matter and antimatter contributions.

The model universes with $\kappa > 0$ we name for shortness the kinetic energy dominated (KED) model universes.

As is evident from the given equations, the contribution by the energy integral in any universe, including the flat model universe, gives the contribution in the form of negative pressure, in this case:

$$P_2 = -\rho_2 \frac{c^2}{3}. \quad (7)$$

Thus, the non-localized integral value of energy can formally be localized, using the term with negative pressure. Thus, the enigmatic accelerating contribution to the expansion of the universe can be attributed simply not to dark energy, but to the excess of the kinetic energy of matter in our expanding KED universe, which at the present epoch gives about 70% of the contribution to the Hubble expansion rate. During early evolutionary stages of the universe, i.e. at the small values of R , this contribution was unnoticeable. The term 'negative pressure' is due to the incorrect interpretation of the term of non-zero total energy integral, reduced to the terms of local equation of state. The used partial contributions can be compared to the Fourier series expansions, where the components do not always have direct physical interpretation.

In order to get a better *Vorstellung* about the role of constant term $\kappa - k$ in Equation (6), we study different possibilities of the interpretation of cosmological scenario in the present era, considering separately the scenarios of the evolution of the universe if it has the flat space, the hyperbolic space or the elliptical space. All of these can be treated by the KED model universes.

In the present state of investigations there is a possibility, which cannot be completely excluded, of abandoning the presumption of the flatness of the universe and accepting the possibility that the universe is hyperbolic. However, both model universes, flat and hyperbolic, have the shortcoming that the universe originates from a self-creational act in the infinite space. In this case, any localization of the Big Bang, even at the very beginning, is excluded. Thus, both the flat and the hyperbolic $k = -1$ universe models have this principal defect in common. Fortunately, there is also a third and principally elegant possibility of the elliptical Bubble universe, which we discuss later in this paper.

3. HYPERBOLIC UNIVERSE WITH INTEGRAL ENERGY AS DARK ENERGY

Let us now start to study different model universes. Many years ago we derived analytical solutions for uniform model universes filled with matter and radiation, for the event (past) and future (particle) light cones therein, for different distances, observables and distributions (Sapar 1964, 1965, 1966, 1970, 1976). Recently (Sapar 2011) we have started to actualize some of the results in the context of progress in observational cosmological studies during the last decades, in particular in connection with the exciting results of studies of the SNe as standard light sources at cosmological redshifts.

In the present section we investigate, which is the evolutionary scenario of the universe if we accept the concept of a hyperbolic universe instead of dark energy in the flat-space universe. For the uniform (isotropic and homogeneous) hyperbolic universe we obtain from Equation (6) in the isotropic co-moving reference frame

the equation

$$\frac{\dot{R}^2}{c^2} = \frac{\alpha}{R} + \frac{\beta}{R^2} + 1. \quad (8)$$

Here α corresponds to the gravitational potential of the matter in the co-moving coordinate frame, and β is the gravitational potential term, corresponding to relativistic particles and radiation. The last term in this equation, treated in the spirit of the Mach principle, is the gravitational potential of the universe. This potential energy of the universe equals to c^2 . The constants used here and in Equation (6) are defined by

$$\alpha = \frac{2GM}{c^2}, \quad M = \frac{4\pi\rho_m R^3}{3}, \quad (9)$$

$$\beta = \frac{2GP}{c^2}, \quad P = \frac{4\pi\rho_r R^4}{3}. \quad (10)$$

In these equations ρ_m and ρ_r are the density of matter and the density of radiation, respectively. From Equation (8) we see that finally the expansion rate of the universe, \dot{R} , differently from the scenario with the cosmological constant, tends to c . As was shown in Sapar (1964, 2011), the integrating gives for the age of the hyperbolic universe an analytical expression

$$ct = Q - \frac{\alpha}{2}\omega, \quad Q = \frac{R\dot{R}}{c} = \sqrt{R^2 + \alpha R + \beta}. \quad (11)$$

Here ω corresponds to the equation of the light cone, which carries us astronomical information of the past events, which locally is defined as the zero-geodetic by

$$c^2 dt^2 = R^2 d\omega^2 = \frac{R_0^2}{(1+z)^2} d\omega^2. \quad (12)$$

The angular distance ω on the light cone is given by

$$\omega = c \int \frac{dt}{R} = c \int \frac{dR}{R\dot{R}} = \ln y, \quad (13)$$

where (Sapar 1964)

$$y = 2Q + 2R + \alpha. \quad (14)$$

The light flux at the geometrical distance D_g is

$$F_g = \frac{L}{S} = \frac{L}{4\pi D_g^2}, \quad D_g = R_0 \omega_z. \quad (15)$$

The luminosity distance D_L is given by the observational flux, F_L , defined by

$$F_L = \frac{L}{S_L} = \frac{L}{4\pi D_L^2}, \quad (16)$$

where the luminosity distance

$$D_L = (1+z)D_g = (1+z)R_0 \sinh \omega_z, \quad (17)$$

and the angular distance

$$\omega_z = \ln \left(\frac{y_0}{y_z} \right). \quad (18)$$

Thus, we obtain

$$\sinh \omega_z = \frac{1}{2} \left(\frac{y_0}{y_z} - \frac{y_z}{y_0} \right). \quad (19)$$

These equations specify the observed brightness values of distant cosmological standard candles, SNe, in a hyperbolic universe. Instead of dark energy the model incorporates the usual energy integral in the hyperbolic space, corresponding to the excess of kinetic energy compared to the potential energy. However, it is necessary to demonstrate that the observed expansion of the universe, at least the results of studies of SNe, can be treated in terms of an expanding hyperbolic universe. Adequacy of such a universe is strongly restricted by the results of cosmological triangulation of the parallax by the Boomerang missions, from which it has been found that with quite high probability the cosmological space of the universe is flat.

The present value of the radial coordinate, R_0 , for a hyperbolic universe is specified from Equation (8) uniquely by

$$R_0 = \frac{c}{H_0} \left(\frac{\alpha}{R_0} + \frac{\beta}{R_0^2} + 1 \right)^{1/2}, \quad (20)$$

where H_0 is the present Hubble constant, $H_0 = \dot{R}_0/R_0$.

4. THE FLAT UNIVERSE WITH AN EXCESS OF KINETIC ENERGY

Here we will consider the flat model universe with an excess of kinetic energy, ignoring the presence of any dark energy (a KED universe). In this case Equation (6) reduces to the form

$$\frac{\dot{R}^2}{c^2} = \frac{\alpha}{R} + \frac{\beta}{R^2} + \kappa. \quad (21)$$

Now we calibrate here the values of R so that $\kappa = 1$. In this way we obtain the equations of the same form as for a hyperbolic universe. The present value of the Hubble constant gives a constraint

$$H_0^2 = \frac{\alpha c^2}{R_0^3} + \frac{\beta c^2}{R_0^4} + \frac{c^2}{R_0^2} \quad (22)$$

between R_0 , α and β for the flat KED universe. To simplify the equations, we take into use the redshift factors $\tau = 1 + z$, obtaining

$$R = \frac{R_0}{\tau}. \quad (23)$$

For the Hubble constant at any redshift now we can write

$$H^2 = \frac{\alpha \tau^3 c^2}{R_0^3} + \frac{\beta \tau^4 c^2}{R_0^4} + \frac{\tau^2}{R_0^2}. \quad (24)$$

For the angular distance from the light cone we obtain the same general expression as for a hyperbolic universe, namely,

$$\omega_z = c \int_t^{t_0} \frac{dt}{R} = c \int_R^{R_0} \frac{dR}{R\dot{R}} = c \int_1^{1+z} \frac{d\tau}{\tau\dot{R}}. \quad (25)$$

Using the Hubble constant, in a similar way as in the case of the hyperbolic space, we obtain

$$\omega_z = \frac{c}{R_0} \int_1^\tau \frac{d\tau}{H} = \ln \left(\frac{y_0}{y_z} \right), \quad (26)$$

where y_z is given by Equation (14).

The luminosity distance in the case of the flat universe is different from that in the hyperbolic space. Namely, in the flat space

$$D_L = R_0(1+z)\omega_z = R_0(1+z) \ln \left(\frac{y_0}{y_z} \right). \quad (27)$$

The equations for the Hubble constant and for the luminosity distance are useful for computing the 'stellar magnitude versus redshift' dependence and for its comparison with the observational brightness values of SNe.

The ratio of the luminosity distances for the hyperbolic and for the flat universe with the kinetic energy excess is given by

$$r_z = \frac{\sinh(\omega_z)}{\omega_z}, \quad \omega_z = \ln \left(\frac{y_0}{y_z} \right). \quad (28)$$

This expression means that the luminosity distance in the hyperbolic space is always larger than in the flat space. From here for the difference of the observed stellar magnitudes we obtain

$$\Delta m_z = 5 \log r_z. \quad (29)$$

Now we estimate the ratio in the case of presently accepted value of α . For small values of ω_z we can write

$$r_z = 1 + \frac{\omega_z^2}{6}. \quad (30)$$

At $z = 1$ we obtain $y_0/y_z \approx 1.67$ and thus, $\omega_z \approx 0.5$, from where $r_z \approx 1.044$. In stellar magnitudes this means that

$$\Delta m_z = 5 \log 1.044 \approx 0.1. \quad (31)$$

This difference is small, and there is no need to make presently the detailed computations both for the curved space and for the flat KED universe.

For the age of the universe we have now

$$ct = \frac{R_0 \dot{R}_0}{c} - \frac{\alpha \Omega_0}{2}, \quad (32)$$

where the angular distance of the past events horizon

$$\Omega_0 = \ln \left(\frac{2R_0\dot{R}_0}{c\alpha} \right). \quad (33)$$

The differences between different model universes diminish in the direction of redshifts. As it has been shown by Aldering et al. (2007), at $1.7 < z < 3$ the evolutionary differences between the model universes give additional differences in apparent stellar magnitudes, which are less than $\Delta m = 0.02$.

Here deserves mentioning that in theoretical cosmology there are two serious studies generalizing the redshift versus magnitude equations, Kaufman & Schucking (1971) and Kaufman (1971), both very detailed and on high mathematical level. The results of these papers were generalized using the Weierstrass elliptical functions by Darbowsky & Stelmach (1986).

5. THE FLAT UNIVERSE WITH COSMOLOGICAL CONSTANT AS DARK ENERGY

A similar analysis of the equations can be carried out for the flat model universe with the cosmological constant Λ , as a version to treat the dark energy. In this case we start from the equation

$$\dot{R}^2 = \frac{\alpha c^2}{R} + \frac{\beta c^2}{R^2} + \frac{\Lambda R^2}{3}. \quad (34)$$

From here we see, that Λ corresponds to $n = 0$, or $w_n = -1$. Thus, we can find the value of Λ corresponding to observations from

$$H_0^2 = \frac{\alpha c^2}{R_0^3} + \frac{\beta c^2}{R_0^4} + \frac{\Lambda}{3}. \quad (35)$$

This equation is a constraint between the values of R_0 , α , β and Λ .

To obtain simpler equations for computations, similarly to the case of the flat KED universe, we take into use the redshift factors $\tau = 1 + z$. For the light cone and for the age of such model universe it is necessary to carry out the numerical computations, because the analytical equation is lacking. This holds also for finding of the dependence 'stellar magnitude versus redshift' to check whether it corresponds to the observational brightness-curve of SNe at large cosmological distances.

6. COMPARISON OF THE HYPERBOLIC AND FLAT MODEL UNIVERSES

We have carried out the computations both for the angular variable ω and the age of the universe using the value $H_0 = 73 \text{ km s}^{-1} \text{ Mpc}^{-1}$ for the present Hubble constant. The corresponding present critical mass density is

$$\rho_{cr} = \frac{3H_0^2}{8\pi G} = 1.0010 \cdot 10^{-29} \quad [\text{g/cm}^3] \quad (36)$$

and the corresponding Hubble age of the universe is $H_0^{-1} = 13.39 \text{ Gyr}$.

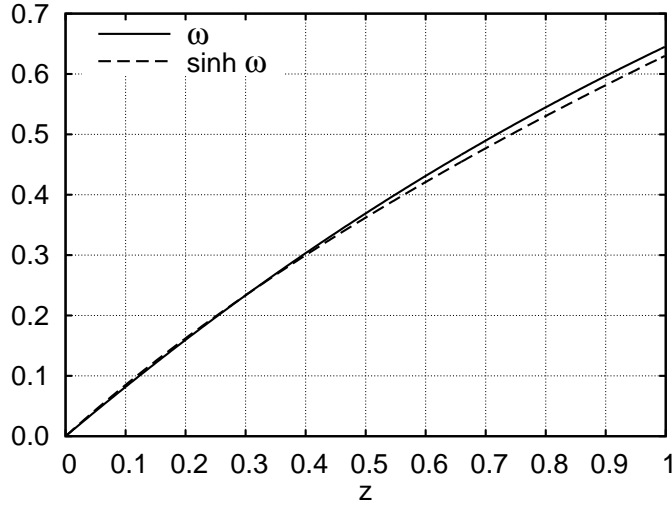


Fig. 1a. The run of the angular variable ω for the flat model universe with cosmological constant (solid curve) and $\sinh \omega$ for a hyperbolic universe (dashed curve) versus the redshift. The difference of curves is rather small.

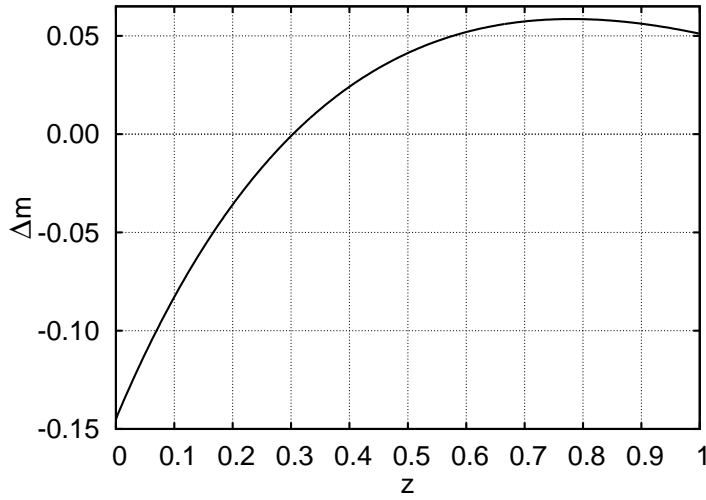


Fig. 1b. The ratio of the luminosity distances for the above described flat and hyperbolic model universes. The difference is quite small and apparently not distinguishable by observations.

We checked different densities of matter to study acceptability of the hyperbolic space for explication of the results of the apparent luminosity versus redshift curves. These curves are treated usually as testimony of urgent need for the cosmological constant in the flat universe. The results suggested to us that it is possible to explain the dependence alternatively, treating the dark energy as an integral of total energy. It corresponds to a very small initial excess of the kinetic

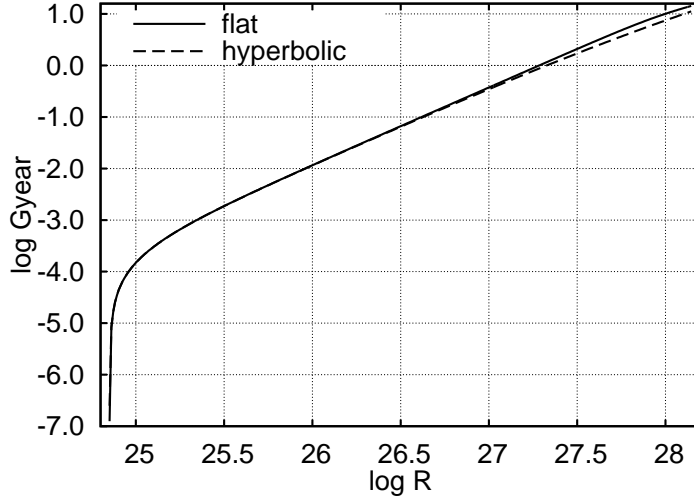


Fig. 2a. The age of the universe versus $\log R$ for the flat model universe with cosmological constant (solid curve) and for a hyperbolic universe (dashed curve).

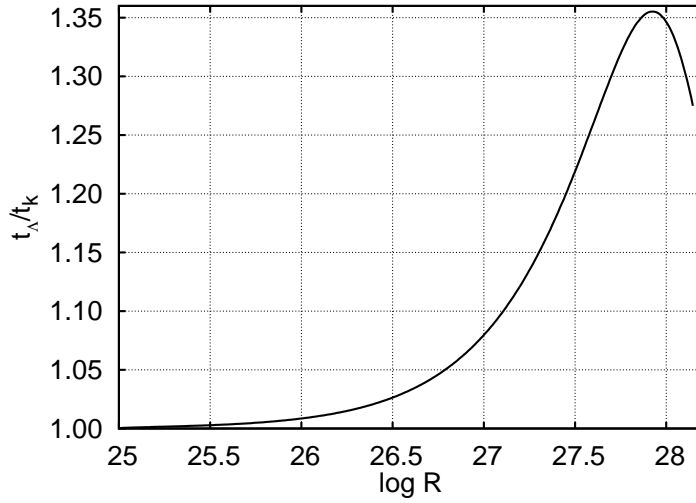


Fig. 2b. The ratio of ages of the above described flat and hyperbolic model universes versus $\log R$. The difference appears starting at $z < 100$.

energy relative to the potential energy of the matter and radiation in the primordial universe. This bias is similar to a small primordial matter and antimatter asymmetry.

As an example, we present here the results of comparison for the flat model universe with the density of matter $\rho_m = 3 \cdot 10^{-30} \text{ g/cm}^3$ and having the cosmological term, and for a hyperbolic universe having the matter density $\rho_m = 2 \cdot 10^{-30} \text{ g/cm}^3$. For both cases the mass density of the radiation was taken to be $\rho_r = 4 \cdot 10^{-34}$

g/cm^3 . The corresponding luminosity ratio in stellar magnitudes, i.e., the expression $\Delta m_z = 5 \log(\omega_\Lambda / \sinh \omega_{-1})$ at $z = 1$ is only 0.051. The respective curves of the luminosity distance factors ω_z and $\sinh \omega_z$ are illustrated in Figure 1a, and their ratio is given in Figure 1b.

The comparison of the run of the model universe ages is given in Figure 2a and their ratio is given in Figure 2b. From Fig. 2a it appears that the evolutionary run of both models is very close. The ages of the universes are respectively $t_\Lambda = 12.92$ Gyr and $t_{-1} = 11.34$ Gyr. Both the hyperbolic and flat KED universes presently do not move to the stage of exponential expansion, as in the case of the presence of the cosmological constant, but are in a transitional stage to the expansion velocity $\dot{R} \Rightarrow c$.

It is seen that the difference in the evolutionary run of the universes begins at $z < 10$. Thus, no essential differences will take place in the formation of inhomogeneities of the CMB, including the formation of its observed structure at large z values, when both models almost coincide. However, the duration of the dark ages and the re-ionization era are somewhat shorter in the case of a hyperbolic universe. Taking into account the Boomerang mission results of cosmological triangulation, which state that our universe is at least quite flat, we conclude that the most appropriate candidate model is the concept of the flat KED universe.

Let us now make a comment about the comparison of the KED model universe with the mostly used flat universe with Λ generating the impelling force. Whereas the value of the Hubble constant in the present epoch is well known and the two first additives with α and β are the same in both model universes, we get the constraint that the third additives must be presently treated as the equal ones, i.e.

$$\frac{\Lambda}{3} = \frac{c^2}{R_0^2}. \quad (37)$$

Thus, it can be treated that instead of the cosmological constant we have a quintessence with the pressure index $-1/3$ which physically corresponds to the energy integral in the flat expanding universe.

7. THE EXPANDING BUBBLE UNIVERSE

In order to overcome the principal difficulty in the Big Bang cosmology, we propose by *Gedankenexperiment*, i.e. an imaginary experiment, the Bubble universe with $k = +1$ and $\kappa = +2$. In this case all the given equations are valid, the world is elliptical and of finite volume. In such a model the luminosity distance has the form

$$D_L = (1 + z)D_g = (1 + z)R_0 \sin \omega_z. \quad (38)$$

In the Bubble universe the Big Bang really took place locally in a 5-dimensional Kaluza-Klein type space, namely in a flat special relativity type world (the four Euclidean spatial coordinates and time), into which our universe can be embedded (Sapar 1964). In this case Equation (28) is to be replaced by

$$r_z = \frac{\sin(\omega_z)}{\omega_z}, \quad \omega_z = \ln \left(\frac{y_0}{y_z} \right). \quad (39)$$

Thus, the luminosity curve of SNe in an elliptical Bubble universe is slightly shifted

in the opposite direction than that in a hyperbolic universe, giving a higher apparent brightness.

Taking into account that at the early evolutionary epochs of the universe all known particles were relativistic, we obtain the equation of evolution for the very early universe:

$$R^2 = 2\sqrt{\beta}ct. \quad (40)$$

Applying this equation to the pre-Planckian universe, starting from $t = 0$, we obtain that at the Planck time, $t_P = (G\hbar/c^5)^{1/2} = 5.39 \cdot 10^{-44}$ s, the radial coordinate R was about $3.42 \cdot 10^{-4}$ cm. At the Planck time this number exceeds the Planck length, $l_P = ct_P$, about 10^{30} times. Traditionally, the needed additional expansion has been ascribed to the inflation of unknown astroparticles – inflatons. The inflationary expansion happens somewhat later than the hypothetical formation of the universe corresponding to the Planck units.

8. A COMMENT ON THE DARK MATTER

Neutrino oscillations are a testimony that neutrinos have a small rest mass. Undoubtedly, neutrinos play in cosmology some role. However, this role is hitherto not sufficiently understood. Let us study shortly the present state of neutrino background in cosmology, accepting that the mean rest energy of electron, muon and tauon type neutrinos is about 1 eV. This means that the mean mass of neutrinos is about $5 \cdot 10^5$ times smaller than m_e .

It is not excluded that the amount of the dark matter is somewhat overestimated, the mass of tauon neutrinos is not firmly determined and, at last, the right-hand neutrinos can exist. Therefore, it is not fully excluded that neutrinos can be one of the main contributors to the dark mass. Now let us briefly describe one important feature of neutrinos related to the observed rotation curves of spiral galaxies.

The decoupled neutrinos on their non-relativistic stage of energies are cooling according to the law $p^2/2m_\nu \propto R^{-2}$. Numerical estimates showed that their temperature in the present epoch is about 10^{-3} K, i.e., their mean velocity is several hundreds km/sec. Such neutrinos in galaxies move predominantly radially, and thus they form wide equipotential wells, which can generate the observed flat rotation velocity curves and accelerate the processes of gravitational clustering during their formation.

9. CONCLUSIONS

The expanding universe can presently be of the KED nature, having dominance of the kinetic energy with respect to the potential energy. In the mainstream cosmology, instead of KED, different other possibilities have been studied. We have modified the traditional approach to the equations of Friedman, introducing the kinetic energy dominance into the flat universe. In this case the final expansion rate of the radial coordinate of the universe tends not to infinity, but to the velocity of light. Thus, the enigmatic dark energy is not more essential in the universe with a small KED originating from the Big Bang era. The situation can be compared with a small asymmetry of the matter and antimatter in the universe.

It is not completely excluded that non-relativistic massive neutrinos contribute to the dark matter background. However, long-term intensive searches of astropar-

ticles have hitherto remained almost without success. The needed massive neutrinos with the rest energy 1–3 eV could cool down to very low temperatures, and they can form the wide equipotential wells in the galaxies, generating the observed flat velocity rotation curves in the outer regions of galaxies.

In the current paradigm the hypothetical anti-gravitational particles, the inflatons, are tunneling the energy from the false vacuum to the real Big Bang. In this way the very hot matter has been created at the conditions of quasi-constant extremely hot temperature, whilst the linear dimensions of the universe have increased by about 30 dex. If we extrapolate our equation even to the zero time considered as the real Big Bang moment, then at the Planckian moment the linear dimensions of the universe have exceeded the Planckian unit of length by about 30 dex, and any inflationary epoch in the evolution of the universe is not compulsory.

However, from the theoretical point of view the most elegant is the possibility of the expanding Bubble universe, in which the creation of the world has been really a local Big Bang in the 5-dimensional pseudo-Euclidean space, removing the usual tacitly accepted concept of the infinite space.

Our revised modeling of the universe and its evolutionary scenario are rather conservative, being based on our aged studies, which have remained almost unnoticed in the West, as it happens frequently with the papers published in Russian. Returning to the problem was mainly stimulated by the recent progress in observational cosmology.

In cosmology the hypothetical and sometimes even paradoxical standpoints have been always an essential part of any concept. Each new achievement here removes some difficulties, but generates new puzzling problems. Thus, all versions of the creation of the universe are somewhat and somehow speculative since they use extraordinary extrapolations far into the past, being based, however, on the laws of physics valid here and now. The hope that one of such extrapolations in its present status is preferable, seems to be a rather overestimated optimism or ignorance of other possibilities.

To summarize, I have tried to demonstrate that the observational data can be interpreted without introducing the dark energy and, possibly, the dark matter of unknown astroparticles. I was encouraged to return to modeling the universe, which was always among my favorite topics, by an inspiring sentence by Saul Perlmutter in his Nobel Lecture: “Everybody talks about the dark energy, but nobody does anything about it”. For myself, I reformulated it as a business slogan in science: “Publish, before you perish”.

ACKNOWLEDGMENTS. This paper has been supported by the research project SF0060030s08 of the Estonian Ministry of Education and Research.

REFERENCES

- Aldering G., Kim A. G., Kowalski M. et al. 2007, *Astroparticle Phys.*, 27, 213
- Astier P., Guy J., Regnault N. et al. 2006, *A&A*, 447, 31
- Dabrowsky M., Stelmach J. 1986, *AJ*, 92, 1272
- Goldhaber G., Perlmutter S. 1998, *Phys. Rep.*, 307, 325
- Kaufman S. E., Schucking E. L. 1971, *AJ*, 76, 583
- Kaufman S.E. 1971, *AJ*, 76, 751
- Leibundgut B. 2009, *A&A*, 500, 615

- MacTavish C. J., Ade P. A. R., Bock J. J. et al. 2006, ApJ, 647, 799
Sapar A. 1964, Tartu Astr. Obs. Publ., 34, 223
Sapar A. 1965, Tartu Astr. Obs. Teated, 13, 1
Sapar A. 1966, Tartu Astr. Obs. Publ., 35, 368
Sapar A. 1970, AZh, 47, 503
Sapar A. 1976, Tartu Astr. Obs. Publ., 44, 21
Sapar A. 2011, Baltic Astronomy, 20, 267